A STUDY OF PLANT DISTRIBUTION IN RELATION TO THE ACIDITY OF VARIOUS SOILS IN MISSOURI

JULIAN A. STEYERMARK

Rufus J. Lackland Research Fellow in the Henry Shaw School of Botany of Washington University

The various kinds of electrometric and colorimetric methods that have been used to determine hydrogen-ion concentration are all relatively recent. Böttger's work in 1897 on the determination of the neutral point in titrating acids with alkalis by use of a gas chain marked the introduction of electrometric methods, and served as an impetus for subsequent workers, such as Hildebrand, Cumming and Gilchrist, Hasselbalch, Clark, Michaelis, Walpole, and others, each of whom helped to perfect the electrometric method. In 1914 the electrometric method was first applied to the measurement of the hydrogen-ion concentration of soil suspensions by Fischer ('14) in Germany, and subsequently in America by Hoagland and Sharp ('18), and by Gillespie ('16) and his co-workers.

In 1909 Sørensen introduced the colorimetric methods, which were later improved and applied to biological fluids by him, Palitzsch, and Walpole. Further improvements were made by Clark and Lubs ('17) in the use of a different set of indicators and buffer mixtures. Biilmann and Lund, in 1921, showed that with quinhydrone it was possible to form an electrode capable of being used for hydrogen-ion determinations, and in 1923 he ('24) applied this electrode in the determination of the hydrogen-ion concentration of soils. The results compared favorably with those of the hydrogen-electrode method. Before Biilmann's discovery the latter method had proven the most satisfactory electrometric method. However, in recent years the quinhydrone electrode has steadily increased in use, and at present seems for various reasons to be superior to the hydrogen electrode. Bayer's ('26) application of this electrode to soil studies has been followed by a number of other workers. The Report of the Committee on Soil Measurements ('30) of the International Society of Soil Science on the "Results of comparative investigations on the quinhydrone electrode method" shows definitely that this method is at present the most satisfactory one.

In the studies reported here a uniform procedure was followed. Soil samples collected on one day were tested in the laboratory on the day following. In practically all cases a 1:1 soil-water ratio was used, being in most instances 500 grams of soil to 500 cc. of water. The mixture of soil and water was shaken violently for approximately one minute, and subsequently allowed to stand an hour. The supernatant liquid was then poured out, and readings made, four or five of which were taken in almost every determination, so that reliable results might be obtained. After each reading the test-tube vessel and electrode were well rinsed with tap and distilled water. Altogether, twenty-four different soil samples were tested. Only surface soils, taken from a depth of about six inches, were used. For most determinations the samples were collected from areas with typical or conspicuous associations rather than from isolated places exhibiting unusual plants. Seven sets of samples were taken. These comprised two sets from Tilsit soil localities, two from two Hagerstown soil localities, one from a Union soil area, one from the so-called "Rough stony land" area, and a final set from a locality possessing Clarksville stony loam soils. The various names given to these soils are those adopted by the Soil Survey of Missouri.

TILSIT SOILS

The belt of Tilsit, like all the belts along the eastern border of the Ozark dome, is very narrow. The Tilsit soils in Jefferson County are derived from the Crystal City or St. Peter sandstone, which is gray to white, and composed of extremely well-rounded, transparent, coarse quartz grains held together very loosely by a small amount of calcareous cement. This sandstone is subject to severe erosion, and deep gorge-like areas and cliff faces are not uncommon.

Set A.—Three samples were obtained on April 14, 1929, along the high sandstone bluffs back from the Meramec River about five miles southeast of Pacific, Jefferson County, Missouri.

Sample 1. This was obtained on the sandstone bluffs, about five feet from the base. A number of plants of *Lycopodium lucidulum* Michx. were growing on a substratum of *Polytrichum commune* L., mats of which grew on the bare sandstone rock. The pH value of the sample was 4.898.

Sample 2. This was taken at the base of the bluffs where the soil was very sandy, on level ground, in shade. A large colony of *Mertensia virginica* (L.) Link grew here. The soil was slightly subalkaline, having a pH of 8.278.

Sample 3. This soil was taken about thirty feet from the base of the bluffs, and was dark brown and not as sandy as that of the previous sample. It came from near the top of a small slope bordering a stream outlet, where *Dicentra Cucullaria* (L.) Bernh. and *D. canadensis* (Goldie) Walp. grew profusely in dense shade. The soil was circumneutral, being pH 6.588. This is one of the few localities in Missouri for *Dicentra canadensis* (Goldie) Walp.

Set B.—Five samples were obtained on May 12, 1929, about six miles southeast of Catawissa, Missouri. In this region occurred the same formation of sandstone as in Set A, which was approximately six miles north.

Sample 1. This was collected on one of the sandstone bluffs that bordered a ravine. The sample was taken about ten feet from the base of the bluff above a spring, where the sandstone was very loose and crumbly. Growing in abundance were *Sullivantia renifolia* Rosendahl (a species never before reported from Missouri), *Hydrangea arborescens* L., and *Marchantia polymorpha* L. The sample was circumneutral, the pH being 7.65.

Sample 2. This was taken on top of a badly weathered sandstone glade, where the rock was exposed and steeply sloping on the brink of the ravine. The sandy soil was thin and scattered, and never reached a depth of over a few inches. The exposure was dry and sunny. *Talinum teretifolium* Pursh and *Polytrichum commune* L. were the chief plants found. On the day the soil was collected a stream, caused by recent rains, was rushing swiftly down the outcrop near the plants, and was washing away much of the soil. The pH of the soil was 5.85.

Sample 3. This was collected in the floor of a deep ravine bordered by high sandstone bluffs. A shallow stream flowed through the valley. There was a rich deciduous tree growth, which shaded the ground plants. The soil was dark brown to slightly black, quite rich, and contained a fair percentage of sand. On the area from which the sample was taken grew *Orchis spectabilis* L., *Corallorrhiza maculata* Raf., and in the immediate envi-

rons was found *Aplectrum hyemale* (Muhl.) Torr. The soil was neutral, its pH being 7.2. The occurrence here of *Orchis spectabilis* L. is to be noted especially, as it is one of the rarest of Missouri plants.

Sample 4. This was procured from the same valley as Sample 3, but nearer the sandstone bluff and nearer the stream, where the soil was sandier. *Orchis spectabilis* L., *Panax quinquefolium* L., and *Smilacina racemosa* (L.) Desf. grew here. The soil was slightly subalkaline, the pH being 8.26.

Sample 5. This sample was taken above a sandstone ravine, in a situation similar to that of sample 2, but at a lower level and at a spot where more soil had accumulated. The exposure was a sunny, mossy slope above a ravine. Here grew an abundance of *Krigia Dandelion* (L.) Nutt. and *Tradescantia bracteata* Small. The soil was very sandy, and of a yellowish brown hue. The pH of the sample was 5.89.

HAGERSTOWN SOILS

The belt of the Hagerstown series, which occurs along the eastern border of the Ozark dome, like that of Tilsit soils, is very narrow. The soil is derived from the Trenton limestone of middle Ordivician age. The rocks are usually chert-free, finely crystalline, rather hard and compact, and of a dark gray color. In Jefferson County the topography in the Hagerstown belt is rough, and considerable areas of limestone glades occur more or less overgrown with *Juniperus virginiana* L.

Set A.—Five samples were collected on May 5, 1929.

Sample 1. This was collected between Imperial and Seckmann, Missouri, on limestone bluffs which were exposed to the sun and subject to drought. The sample was from cracks or narrow ledges on the rock where a small amount of soil had accumulated. A great abundance of *Cheilanthes Feei* Moore was observed. Plants associated with it were *Aquilegia canadensis* L., *Hydrangea arborescens* L., and *Heuchera hirsuticaulis* (Wheelock) Rydb. The soil was slightly subalkaline, having a pH of 8.482.

Sample 2. This was taken between Imperial and Seckmann, Missouri, in wet soil, in an open valley exposed to the sun and about 30 feet from a road. The soil of the valley floor probably received some alluvial deposits from Rock Creek, a stream about

150 yards distant. It may have also received material from the high limestone hills about 15 yards away, in the opposite direction from that of the stream. The plants found growing in this soil were *Acorus Calamus* L., *Typha latifolia* L., and *Mentha spicata* L. The pH of the soil was 7.285.

Sample 3. This was taken about two miles southwest of Glen Park, Missouri, at the head of a valley leading into a ravine. A stream flowed near by. The woods were dominated by oaks, chiefly *Quercus alba* L. and *Quercus rubra* L. The ground plants growing here were *Erigeron pulchellus* Michx., *Krigia amplexicaulis* Nutt., *Tradescantia bracteata* Small, *Phlox divaricata* L. with a rose-red corolla, and *Cornus florida* L. The soil was free from stones, and had a pH of 6.826.

Sample 4. This was collected about 100 yards from the previous sample, in a dry, mossy, sunny thicket, bordering on open oak woods, near the lower portion of the hill. *Castilleja coccinea* (L.) Spreng. in abundance, *Pedicularis canadensis* L., *Heuchera hirsuticaulis* (Wheelock) Rydb., *Geranium maculatum* L., *Erigeron pulchellus* Michx., *Krigia amplexicaulis* Nutt., *Ranunculus fascicularis* Muhl., and *Polystichum acrostichoides* (Michx.) Schott occurred here. The soil was a light brown clay, stone-free, and was subacid, having a pH of 5.806.

Sample 5. This was collected about one mile northwest of Barnhart, Missouri, near the top of a high, cherty limestone hillside, with a southern exposure, and consequently dry and exposed to the sun. The locality was a glade type, and bordered on a thicket of post oak and black-jack oak. The plants growing here were *Monarda Bradburiana* Beck, *Zizia aurea* (L.) Koch, *Brauneria angustifolia* (DC.) Heller, and *Parthenium integrifolium* L. The pH of the soil was 7.438.

Set B.—There were five samples of soil included in this second set, collected on May 20, 1929. The area was six miles west-southwest of Pevely, and approximately six miles distant from that from which the previous soil samples were taken. This country has considerable areas of limestone glades grown over with *Juniperus virginiana* L.

Sample 1. This was obtained halfway up a limestone hill. The surface limestone was broken into fragments, leaving exposed a

bare rocky glade, with sunny exposure, bordered by cedar trees. *Oxalis violacea* L., *Brauneria angustifolia* (DC.) Heller, *Houstonia longifolia* Gaertn., *Viola pedata* L., *Agave virginica* L., and *Psoralea tenuiflora* Pursh were found here. The soil was subalkaline, its pH being 8.448.

Sample 2. This was collected in rich limestone woods, about halfway up a steep, wooded and densely shaded hill. *Tilia americana* L., *Acer saccharum* Marsh., *Cornus florida* L., *Carya cordiformis* (Wang.) K. Koch, *Ulmus americana* L., and several species of *Quercus* were growing here. Towards the base, massive limestone outcrops occurred. A sample of soil was taken near a huge limestone boulder, where there grew several plants of *Aquilegia canadensis* L. and *Cystopteris bulbifera* L. The soil was dark brown in color and slightly alkaline, its pH being 8.363.

Sample 3. This was taken on the floor of a limestone ravine, near a stream. There was a heavy growth of *Acer saccharum* Marsh., *Ulmus americana* L., *Benzoin aestivale* (L.) Nees, *Aesculus glabra* Willd., and *Quercus alba* L., which shaded the ground plants. *Corallorrhiza maculata* Raf., *Viola striata* Ait., and *Botrychium virginianum* (L.) Sw. were in the immediate vicinity. The soil was a rich stony loam with much humus, and of a dark brown color. It was found to be slightly subalkaline, having a pH of 8.227.

Sample 4. This sample was dug about one-third the way up a thinly shaded hill covered chiefly with several species of *Quercus*, some *Cornus florida* L., and a few species of *Carya*. The soil was dark brown, thickly covered in most places with oak leaves, and was, on the whole, stone-free. The plants found growing here were *Rosa humilis* Marsh., *Antennaria plantaginifolia* (L.) Richards., *Rubus occidentalis* L., *Vaccinium vacillans* Kalm, and *Cunila origanoides* (L.) Britton. The soil was neutral, having a pH of 7.081.

Sample 5. This was collected in soil full of fragments of chert and pure limestone, at the base of a hill covered with oak and hickory. The spot was located just above the bank of a stream and opposite the hill from which the previous sample was collected. The woods here were rather open. The plants found were *Baptisia bracteata* (Muhl.) Ell., *Viola pedata* L., *Monarda Bradburiana*

Beck, *Antennaria plantaginifolia* (L.) Richards., and *Polygonatum commutatum* (R. & S.) Dietr. The soil was of a reddish-brown color, stony, and argillaceous. It was found to be subacid, and its pH 5.89.

UNION SOILS

This comprised a set of soils gathered at Gray Summit, Franklin County, Missouri. The rocks from which the Union soils are derived are the Jefferson City or Beekmantown limestones, of lower Ordivician time; these rocks are a series of moderately cherty, argillaceous, and more or less shaly and thinly bedded limestones. The topography in Franklin County where the Union soils occur is rather rough. All of the samples were collected on slopes where the soil was very shallow and the bedrock was exposed, making limestone glades. *Juniperus virginiana* L. and *Crataegus berberifolia* T. & G. var. *Engelmanni* (Sarg.) Eggleston were collected April 28, 1929. Four soil samples were obtained.

Sample 1. This was obtained under cedar trees, about three-fourths up a slope of a dry, cherty and argillaceous limestone glade. *Dodecatheon Meadia* L., *Astragalus distortus* T. & G., *A. mexicanus* A. DC., and *Lithospermum canescens* (Michx.) Lehm. grew here. The soil was of a yellowish brown color, with a pH of. 8.00.

Sample 2. This sample was dug from dry soil on a slope in cedar woods, about halfway down a hill, where cherty to pure limestone rocks outcropped. The soil was deeper and less rocky here, and of a dark brown color. *Smilax ecirrhata* (Engelm.) Wats., *Polygonatum commutatum* (R. & S.) Dietr., *Botrychium virginianum* (L.) Sw., *Camassia esculenta* (Ker.) Robinson, and *Galium circaezans* Michx. were growing here. The sample was found to be subalkaline, its pH being 8.41.

Sample 3. This was collected on top of a cherty to pure limestone glade, in strong sun, in a large open area surrounded by cedars. The soil consisted almost solely of rock fragments. *Arenaria patula* Michx., *Scutellaria parvula* Michx., *Psoralea tenuiflora* Pursh, and *Petalostemum purpureum* (Vent.) Rydb. were the plant associates. The soil tested was circumneutral, its pH being 8.19.

Sample 4. This was from a similar locality to that of the previous sample, except that the glade was wider and cedars were

found only below and above the barren rock portion. Here were found *Oenothera missouriensis* Sims, *Viola pedata* L., *Sisyrinchium angustifolium* Mill., *Hypoxis hirsuta* (L.) Coville, *Brauneria angustifolia* (DC.) Heller, and *Coreopsis lanceolata* L. The soil was dry, exposed to the sun, and pure limestone rock predominated. It was found to have the same pH as that of sample 1, namely, pH 8.00.

ROUGH STONY LAND SOIL

The soil group classed under this head is derived from igneous rocks consisting of granites, rhyolites, trachytes, and diabase, the most abundant being a dense, hard porphyritic trachyte. The topography of this region is very rough.

One sample was collected from an area opposite Pilot Knob, in Iron County, on April 21, 1929.

Sample 1. This was from a dry sunny hillside opposite Pilot Knob, about a quarter of the distance up a 400-foot slope. It was taken from between rocks of porphyritic trachyte, surrounded by huge boulders. The trees consisted chiefly of second- and third-growth oak and hickory. The ground plants found here associated were *Tradescantia brevicaulis* Raf., *Vaccinium arboreum* Marsh., *Viola pedata* L., and *V. palmata* L. The soil was grayish brown in color, and its pH was 7.089.

CLARKSVILLE SOILS

These soils are mainly stony loams and are derived from the upper Cambrian (Ozarkian) beds of Gasconade cherty limestone, with a basal formation of Gunter sandstone. The areas of Clarksville soils are the most thoroughly dissected of any of the important soil areas of the Ozark dome. One sample was obtained through the kindness of Miss Marion Child, who dug it in Pulaski County, about twelve miles southwest of Dixon, on March 31, 1929.

The sample was obtained on top of a sun-exposed bluff which faced the Gasconade River. There were outcroppings of the Gunter sandstone, and the soil was a fine, sandy, cherty loam, brownish-red in color. Red cedars grew plentifully in the area. Other plants found here were *Verbena canadensis* (L.) Britton, *Lithospermum canescens* (Michx.) Lehm., and *Verbascum Thapsus* L. The soil was circumneutral, its pH being 7.819.

It will be seen from the foregoing account of the work that most of the soils ranged from minimacid to subalkaline, only five of the twenty-four soils tested showing any marked acidity.

No broad generalizations can be made from the limited range of the present piece of work, since the soils were obtained from comparatively few areas, and none was worked in detail. The effort in this investigation was to obtain a reconnaissance of the soil acidities of eastern Missouri, with a list of some characteristic plants on each soil type.

As stated by others, the fact that a given plant is found in soils of a certain degree of acidity or alkalinity does not necessarily indicate that the pH concentration is the all-important factor in determining where the plant grows; nor even that it acts directly upon the plant. It is the opinion of plant physiologists generally that the question of pH has been unduly emphasized as the dominant factor in plant distribution in relation to soil acidity. It appears more and more evident that the distribution of any given plant is the result of a number of factors; of these factors soil acidity or alkalinity and its relationship with hydrogen-ion concentration may be of significance or it may not.

Wherry ('20) has shown that plants grow in nature only when the hydrogen-ion concentration is within certain limits. Sometimes the range may be quite large, and at other times quite narrow. Arrhenius ('20) has studied the "Skärs" around Stockholm, Sweden, and he finds that among the factors influencing plant distribution hydrogen-ion concentration plays a very important rôle. Atkins ('22), in Ireland, is another to have studied the relation between plant distribution and soil acidity. Braun-Blanquet ('24), studying the vegetation of the Mediterranean, found that the hydrogen-ion concentration seems to be the factor in determining the distribution of the so-called calcicoles (lime-growers) rather than the lime. It is thus seen that several investigators in widely separated places have found that plants in nature are greatly influenced by the active acidity of the soil.

Wherever possible the results of the present work were compared with those of Wherry, and in most cases the results checked well. In a number of instances, however, it was found that whereas Wherry had placed a species in a definite class, the present

work indicated that this species is more or less indifferent and grows in a wide acid range. For instance, *Viola pedata* L. is almost always referred to as a subacid to minimacid soil plant, whereas the present work showed it has a range from pH 5.89 to pH 8.448, or in other words, from subacid to decidedly subalkaline. Time and again, *Viola pedata* L. was found on limestone substratum, a fact that would indicate alkalinity. In the case of this plant, which grows usually in dry, sunny, rocky or mossy places, the question appears to be one concerned with water content in the soil rather than of soil acidity.

Other examples of apparent differences are as follows: (1) *Botrychium virginianum* (L.) Sw. is classified as a subacid soil plant; the present work shows this species taking subalkaline conditions. (2) *Hypoxis hirsuta* (L.) Coville and *Lithospermum canescens* (Michx.) Lehm., usually classified as subacid soil plants, were found to take minimalkaline conditions.

There are other apparent instances, also. The present work would lead the writer to believe that there are many plants it would be erroneous to treat as of a definite soil type, for results show that usually these plants are indifferent towards soil pH and will accept quite a range of acidity and alkalinity. Such plants, it is felt, seem to be influenced greatly by water content of the soil or by a combination of other factors, in addition to that of soil acidity. In some cases, it seems unquestionably true that the distribution of certain plants is affected by the soil acidity; in some cases this soil acidity can be traced back to the water relationship in the soil, and in others it cannot. On the other hand, very often the factor of soil acidity does not seem to be the most important one to be considered. It would seem that a number of factors in certain combinations or ratios have much to do with affecting the distribution of a plant, rather than any single factor, such as that of soil acidity.

This work was carried on in the spring of 1929 in the Plant Physiological Laboratory of Washington University, under the kind supervision of Dr. E. S. Reynolds.

COMPARISONS BETWEEN WHERRY'S SOIL ACIDITY RESULTS AND THOSE OF THE PRESENT WORK

Plant	Soil type	Acidity found in present work	Acidity found by Wherry
Lycopodium lucidulum Michx.	Tilsit	pH 4.898 (mediacid)	
Castilleja coccinea (L.) Spreng.	Hagerstown	pH 5.806 (subacid)	
**Krigia amplexicaulis* Nutt.	Hagerstown	pH 5.806 (subacid)	
Pedicularis canadensis L.	Hagerstown	pH 5.806 (subacid)	Minimacid
**Heuchera hirsuticaulis* (Wheelock) Rydb.	Hagerstown	pH 5.806 (subacid)	Indifferent
Geranium maculatum L.	Hagerstown	pH 5.806 (subacid)	Indifferent
**Erigeron pulchellus* Michx.	Hagerstown	pH 5.806 (subacid)	Indifferent
Polystichum acrostichoides (Michx.) Schott	Hagerstown	pH 5.806 (subacid)	Indifferent
Ranunculus fascicularis Muhl.	Hagerstown	pH 5.806 (subacid)	Minimacid
Talinum teretifolium Pursh	Tilsit	pH 5.85 (subacid)	
Polytrichum commune L.	Tilsit	pH 5.85 (subacid)	
Krigia Dandelion (L.) Nutt.	Tilsit	pH 5.89 (subacid)	
**Tradescantia bracteata* Small	Tilsit	pH 5.89 (subacid)	
Baptisia bracteosa (Muhl.) Ell.	Hagerstown	pH 5.89 (subacid)	
**Viola pedata* L.	Hagerstown	pH 5.89 (subacid)	Subacid and Minimacid
**Monarda Bradburiana* Beck	Hagerstown	pH 5.89 (subacid)	
**Antennaria plantaginifolia* (L.) Richards.	Hagerstown	pH 5.89 (subacid)	Minimacid
**Polygonatum commutatum* (R. & S.) Richards.	Hagerstown	pH 5.89 (subacid)	
Dicentra canadensis (Goldie) Walp.	Tilsit	pH 6.58 (circum-neutral)	Circumneutral
Dicentra Cucullaria (L.) Bernh.	Tilsit	pH 6.58 (circum-neutral)	Circumneutral
Phlox divaricata L.	Hagerstown	pH 6.826 (circum-neutral)	Circumneutral
**Erigeron pulchellus* Michx.	Hagerstown	pH 6.826 (circum-neutral	Circumneutral
**Krigia amplexicaulis* Nutt.	Hagerstown	pH 6.826 (circum-neutral)	Circumneutral
**Tradescantia bracteata* Small	Hagerstown	pH 6.826 (circum-neutral)	Circumneutral
Cornus florida L.	Hagerstown	pH 6. 826(circum-neutral)	Minimacid
Rosa humilis Marsh.	Hagerstown	pH 7.081 (neutral)	
Vaccinium vacillans Kalm	Hagerstown	pH 7.081 (neutral)	Subacid
**Antennaria plantaginifolia* (L.) Richards.	Hagerstown	pH 7.081 (neutral)	Minimacid
Cunila origanoides (L.) Britton	Hagerstown	pH 7.081 (neutral)	
Rubus occidentalis L.	Hagerstown	pH 7.081 (neutral)	
Tradescantia brevicaulis Raf.	"Rough stony land"	pH 7.089 (neutral)	Subacid
Vaccinium arboreum Marsh.	"Rough stony land"	pH 7.089 (neutral)	
**Viola pedata* L.	"Rough stony land"	pH 7.089 (neutral)	Subacid or Minimacid
Viola palmata L.	"Rough stony land"	pH 7.089 (neutral)	
Orchis spectabilis L.	Tilsit	pH 7.2 (neutral	Circumneutral
Aplectrum hyemale (Muhl.) Torr.	Tilsit	pH 7.2 (neutral)	
**Corallorrhiza maculata* Raf.	Tilsit	pH 7.2 (neutral)	

Plant	Soil type	Acidity found in present work	Acidity found by Wherry
Acorus Calamus L.	Hagerstown	pH 7.285 (neutral)	
Mentha spicata L.	Hagerstown	pH 7.285 (neutral)	
Typha latifolia L.	Hagerstown	pH 7.285 (neutral)	
**Monarda Bradburiana* Beck	Hagerstown	pH 7.438 (circum-neutral)	
Zizia aurea (L.) Koch	Hagerstown	pH 7.438 (circum-neutral)	Circumneutral
Parthenium integrifolium L.	Hagerstown	pH 7.438 (circum-neutral)	
**Brauneria angustifolia* (DC.) Heller	Hagerstown	pH 7.438 (circum-neutral)	
Sullivantia renifolia Rosendahl	Tilsit	pH 7.65 (circum-neutral)	Indifferent for *S. Sullivantii* (T. & G.) Britton
**Hydrangea arborescens* L.	Tilsit	pH 7.65 (circum-neutral)	
Marchantia polymorpha L.	Tilsit	pH 7.65 (circum-neutral)	
Hypoxis hirsuta (L.) Coville	Union	pH 8.00 (circum-neutral)	Subacid
Sisyrinchium angustifolium Mill.	Union	pH 8.00 (circum-neutral)	
Oenothera missouriensis Sims	Union	pH 8.00 (circum-neutral)	
**Brauneria angustifolia* (DC.) Heller	Union	pH 8.00 (circum-neutral)	
**Viola pedata* L.	Union	pH 8.00 (circum-neutral)	Subacid or minimacid
Dodecatheon Meadia L.	Union	pH 8.00 (circum-neutral)	Circumneutral
Astragalus distorta T. & G.	Union	pH 8.00 (circum-neutral)	
Astragalus mexicanus A. DC.	Union	pH 8.00 (circum-neutral)	
**Lithospermum canescens* (Michx.) Lehm.	Union	pH 8.00 (circum-neutral)	Minimacid
Arenaria patula Michx.	Union	pH 8.19 (circum-neutral)	
Scutellaria parvula Michx.	Union	pH 8.19 (circum-neutral)	
**Psoralea tenuiflora* Pursh	Union	pH 8.19 (circum-neutral)	
Petalostemum purpureum (Vent.) Rydb.	Union	pH 8.19 (circum-neutral)	
Corallorrhiza maculata Raf.	Hagerstown	pH 8.227 (slightly subalkaline)	
Viola striata Ait.	Hagerstown	pH 8.227 (slightly subalkaline)	
**Botrychium virginianum* (L.) Sw.	Hagerstown	pH 8.227 (slightly subalkaline)	Subacid
Orchis spectabilis L.	Tilsit	pH 8.26 (slightly subalkaline)	Circumneutral
Smilacina racemosa (L.) Desf.	Tilsit	pH 8.26 (slightly subalkaline)	Indifferent
Panax quinquefolium L.	Tilsit	pH 8.26 (slightly subalkaline)	

Plant	Soil type	Acidity found in present work	Acidity found by Wherry
Mertensia virginica (L.) Link	Tilsit	pH 8.278 (slightly subalkaline)	Circumneutral
**Aquilegia canadensis* L.	Hagerstown	pH 8.363 (subalkaline)	Circumneutral
Cystopteris bulbifera L.	Hagerstown	pH 8.363 (subalkaline)	Circumneutral
Smilax ecirrhata (Engelm.) Wats.	Union	pH 8.41 (subalkaline)	
**Polygonatum commutatum* (R. & S.) Dietr.	Union	pH 8.41 (subalkaline)	
**Botrychium virginianum* (L.) Sw.	Union	pH 8.41 (subalkaline)	Subacid
Camassia esculenta (Ker.) Robinson	Union	pH 8.41 (subalkaline)	
Galium circaezans Michx.	Union	pH 8.41 (subalkaline)	
**Psoralea pedunculata* Pursh.	Hagerstown	pH 8.448 (subalkaline)	
Agave virginica L.	Hagerstown	pH 8.448	
**Viola pedata* L.	Hagerstown	pH 8.448	Subacid
Houstonia longifolia Gaertn.	Hagerstown	pH 8.448	
Oxalis violacea L.	Hagerstown	pH 8.448	Indifferent
Cheilanthes Feei Moore	Hagerstown	pH 8.482	Circumneutral to subacid
**Aquilegia canadensis* L.	Hagerstown	pH 8.482	Circumneutral
**Hydrangea arborescens* L.	Hagerstown	pH 8.482	
**Heuchera hirsuticaulis* (Wheelock) Rydb.	Hagerstown	pH 8.482	Indifferent

* Denotes wide range of pH.

Bibliography

Arrhenius, O. ('20). Öcologische Studien in den Stockholmer Schären. Stockholm. 1920. [Cited by Atkins, '22.]

Atkins, W. R. G. ('22). Some factors affecting the hydrogen-ion concentration of the soil and its relation to plant distribution. Royal Dublin Soc., Sci. Proc. **16:** 369–413.

Bayer, L. D. ('26). The use of the quinhydrone electrode for measuring the hydrogen-ion concentration of soils. Soil Sci. **21:** 167–179. 1926.

Biilmann, E. ('24). On the measurement of hydrogen-ion concentrations in soil by means of the quinhydrone electrode. Jour. Agr. Sci. **14:** 232–239. 1924.

————, et Lund, H. ('21). Sur l'electrode à quinhydrone. Ann. de Chim. IX. **16:** 321–340. 1921.

Böttger, W. ('97). Die Anwendung des Elektrometres als Indikator beim Titrieren von Säuren und Basen. Zeitschr. f. phys. Chem. **24:** 253–311. 1897.

Braun-Blanquet, J. ('24). Etudes sur la végétation méditerranéenne. III. Concentration en ions H et calcimétrie du sol de quelques associations de la garigue languedocienne. Soc. Bot. France, Bull. **71:** 639–647. 1924.

Brioux, C., et Pien, J. ('25). Emploi de l'electrode à quinhydrone pour la détermination du P_H des sols. Acad. Paris, Compt. Rend. **181:** 141–143. 1925.

Clark, W. M. ('20). The determination of H-ions. Baltimore, 1920.

Clark, W. M., and Lubs, H. A. ('17). The colorimetric determination of hydrogen ion concentration and its applications in bacteriology. Jour. Bact. **2**: 109, 191. 1917.

Committee on Soil Reaction Measurements ('30). Report, Part I. Results of comparative investigations on the quinhydrone electrode method. Internat. Soc. Soil Sci., Suppl. to Proc. **2**. 1930.

Coville, F. V. ('10). Experiments on blueberry culture. U. S. Dept. Agr., Bur. Pl. Ind. Bull. 193: 1–100. 1910.

Fischer, G. ('14). Die Säuren und Kolloide des Humus. Kühn-Arch. **4**: 1–136. 1914.

Gillespie, L. J. ('16). The reaction of soil and measurements of hydrogen-ion concentration. Wash. Acad. Sci., Jour. **6**: 7–16. 1916.

Gustafson, F. G. ('26). Plant distribution as affected by hydrogen-ion concentration of the soil. Mich. Acad. Sci. Papers **6**: 237–246. 1926.

Hilbig, R. ('26). Der Einfluss der Bodenreaktion auf das Wachstum der Pflanzen. Bot. Arch. **15**: 385–423. 1926.

Hoagland, D. R., and Sharp, L. T. ('18). Relation of carbon dioxide to soil reaction as measured by the hydrogen electrode. Jour. Agr. Res. **12**: 139–148. 1918.

La Mer, V. K., and Parsons, T. R. ('23). The application of the quinhydrone electrode to electrometric acid-base titrations in the presence of air and the factors limiting its use in alkaline solutions. Jour. Biol. Chem. **57**: 613–631. 1923.

Leffmann, H. ('24). Hydrogen-ion concentration in relation to animal and plant growth. Franklin Inst., Jour. **197**: 741–756. 1924.

Marbut, C. F. ('11). Soil reconnaissance of the Ozark region of Missouri and Arkansas. U. S. Dept. Agr., Bur. Soils, Field Operations Rept. **13**: 1727–1873. 1911.

Olsen, C. ('23). Studies on the hydrogen-ion concentration of the soil and its significance to the vegetation, especially to the natural distribution of plants. Carlsb. Lab., Compt. Rend. **15**: 1–166. 1923.

Powers, W. L. ('27). The effect of hydrogen-ion concentration on the growth of certain plants. Soil Sci. **24**: 1–7. 1927.

Salter, R. M., and Morgan, M. F. ('23). Factors affecting the soil reaction. I. Soil-water ratio. Jour. Phys. Chem. **27**: 117–140. 1923.

Salisbury, E. J. ('22). Stratification and hydrogen-ion concentration of the soil in relation to leaching and plant succession with special reference to woodlands. Jour. Ecol. **9**: 220–240. 1922.

Schollenberger, C. J. ('25). An improved calomel electrode. Indus. and Engin. Chem. **17**: 649. 1925.

Sørensen, S. P. L. ('09). Études enzymatiques. II. Sur la mesure et l'importance de la concentration des ions hydrogène dans les réactions enzymatiques. Carlsb. Lab., Compt. Rend. **8**: 1–168. 1909.

Trümpener, E. ('26). Über die Bedeutung der Wasserstoffionenkonzentration für die Verbreitung von Flechten. Beih. bot. Centralbl. **42**[1]: 321–354. 1926.

Waksman, S. A. ('24). Influence of soil reaction upon the distribution of filamentous fungi in the soil. Ecol. **5**: 54–59. 1924.

Wherry, E. T. ('18). The reaction of the soils supporting the growth of certain native orchids. Wash. Acad. Sci., Jour. **8**: 589–598. 1918.

————, ('20a). Correlation between vegetation and soil acidity in southern New Jersey. Acad. Nat. Sci. Phila., Proc. **72**: 113–119. 1920.

Wherry, E. T. ('20b). Observations on the soil acidity of Ericaceae and associated plants in the middle Atlantic States. *Ibid.* 84–111. 1920.

————, ('20c). Plant distribution around salt marshes in relation to soil acidity. Ecol. **1**: 42–48. 1920.

————, ('20d). The soil reactions of certain rock ferns. I. Amer. Fern Jour. **10**: 15–22. 1920.

————, ('20e). Soil tests of Ericaceae and other reaction-sensitive families in northern Vermont and New Hampshire. Rhodora **22**: 33–49. 1920.

————, ('22). Soil acidity—its nature, measurement and relation to plant distribution. Smiths. Inst., Ann. Rept. **1920**: 247–268. 1922.

————, ('27a). Determining soil acidity and alkalinity by indicators in the field. Wash. Acad. Sci., Jour. **10**: 217–223. 1927.

————, ('27b). The soil-reaction preferences of certain plant orders. *Ibid.* **17**: 148–149. 1927.

————, ('27c). The soil reactions of some saprophytic orchids. *Ibid.* 35–38. 1927.